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**ABSTRACT**

Various stock types of white spruce (Picea glauca (Moench) Voss), white pine (Pinus strobus L.) and red pine (Pinus resinosa Ait.) were planted on several sites with large variation in degree of vegetative competition. Field performance of the stock varied with stock type and vegetative competition. Stronger, more robust seedlings performed better than less robust seedlings on all sites but these differences increased with increasing vegetative competition. Smaller, less costly, stock performed satisfactorily on low competition sites. On sites with intense competition, only heavy transplant stock attained acceptable growth and survival.

We recommend that the more expensive transplant stock should be planted on more difficult sites while the less costly seedling stock could be planted on low competition sites.

A program of stock-type testing is recommended to identify the suitability of new stock types for specific sites.

## Introduction

Bare root nursery stock production practices in Ontario are chiefly regulated by monitoring the physical characteristics of the stock. The general size distributions of shipping stock have been described by Reese and Sadreika (1979) who characterized the stock by size (large, medium and small) and age class. Individual stock dimensions are also frequently used for culling and grading because they have a demonstrated effect on stock performance in the field (Mullin and Christl 1981, 1982; Chavasse 1977).

Nursery cultural practices effect the physical dimensions of the seedlings produced. One of these cultural practices is transplanting, which reduces density, increases uniformity by excluding inferior or malformed seedlings, resulting in robust, well balanced trees with a dense, fibrous root system. The main difference between seedlings and transplants, also referred to as age-class differences, is that the latter is a better balanced tree than seedling stock.

To define stock simply by age-class is inadequate because the morphological and physiological state of stock is also influenced by various other nursery cultural practices. It is, therefore, better to refer to stock type than to age-class because the former gives a better indication of the cultural practices used.

The only true test of stock quality is field performance under normal field conditions. The key feature of field conditions is their variability (Hills 1960). It is, therefore, important that various stock types are evaluated over a range of sites on which the species is normally planted. Stock types which perform well on specific sites should be planted on these sites, thereby optimizing the regeneration effort.

Matching stock type and/or species to site has been a silvicultural problem of long standing and the only way to solve it is by conducting many comparative outplantings on many different sites.

The objective of this report is to examine the results of several trials in which various stock types were outplanted on a variety of sites and to show how stock types can be matched to site and therefore reduce plantation establishment costs.

## Materials and Methods

Three series of outplantings were established. Two plantations of white spruce (*Picea glauca* (Moench) Voss) were established in 1977, five plantations of white pine (*Pinus strobus* L.) in 1980 and three plantations of red pine (*Pinus resinosa* Ait.) in 1981. In each of these plantations, various stock types (Table 1) were outplanted. Plantation locations were selected to represent a range of field conditions.

White spruce from the Midhurst tree nursery (43°30'N, 79°45'W) was planted as 2+0 and 3+0 seedlings and 1.5+1.5 transplants on May 3 and 4, 1977. The sites at the Midhurst Research Station consisted of a farm field in sod and a cultivated field. The soil was a deep, fine sandy loam in

Table 1 Morphological characteristics of the various stock types used in this study. (n=50)

| Stock type | Nursery | Site region[1] | Shoot length cm | Stem diameter cm | Shoot weight[3] g | Root weight[3] g |
|---|---|---|---|---|---|---|
| White spruce | | | | | | |
| 2+0 | Midhurst | 6200 | 18.2 | 0.37 | 2.57 | 0.56 |
| 3+0 | Midhurst | 6200 | 29.0 | 0.46 | 5.20 | 1.31 |
| 1.5+1.5 | Midhurst | 6200 | 36.1 | 0.68 | 11.26 | 3.90 |
| White pine | | | | | | |
| 3+0 | Midhurst | 5200 | 23.4 | 0.46 | 5.61 | 2.11 |
| 1+2 | Midhurst | 5200 | 19.8 | 0.62 | 11.71 | 5.59 |
| 2+1 | Midhurst | 5200 | 18.8 | 0.51 | 6.38 | 4.47 |
| 2+2 | Midhurst | 5200 | 26.2 | 0.74 | 15.78 | 7.62 |
| 3+0 | Kemptville | 5200 | 25.7 | 0.52 | 6.73 | 2.11 |
| Red pine | | | | | | |
| 3+0 | Orono | 6200 | 29.4 | 0.50 | 8.99 | 2.06 |
| 2+1 | Orono | 6200 | 19.1 | 0.52 | 6.73 | 2.85 |
| 3+0 | Midhurst | 6200 | 29.1 | 0.52 | 7.77 | 1.63 |
| 1+2 | Midhurst | 6200 | 24.6 | 0.79 | 15.85 | 4.18 |
| 2+0 | Midhurst[2] | 6200 | 10.1 | 0.40 | 3.59 | 0.85 |
| 3+0 | Midhurst[2] | 6200 | 26.8 | 0.50 | 6.65 | 1.75 |
| 1+2 | Midhurst[2] | 6200 | 22.2 | 0.81 | 16.85 | 5.77 |
| 1+1 | Kemptville | 5200 | 7.8 | 0.40 | 3.19 | 0.95 |
| 2+0 | Kemptville | 6200 | 7.3 | 0.31 | 1.88 | 0.75 |
| 3+0 | Kemptville | 6200 | 26.8 | 0.47 | 5.42 | 1.08 |

[1] Seed source is identified by site region (Hills 1960).
[2] Only planted at the Midhurst nursery.
[3] Oven-dried weights.

both fields. The sod site (after cultivating) was sown with white Dutch clover (Trifolium repens) and timothy (Phleum pratense) in 1975, but at the time of planting consisted mainly of weed species including grasses, goldenrod (Solidago sp.), clover (Trifolium sp.), carrot (Daucus carota), dandelion (Taraxacum officinale), plantain (Plantago sp.), shepherds purse (Capsella sp.) and some hardwood seedlings (Acer rubium and Tilia sp.). The cultivated site was summer fallowed in 1976 and cultivation was maintained to the end of the first growing season. In the spring of 1978 white Dutch clover was sown between the rows of trees and mowed regularly. Trees were planted in a randomized complete block design with three stock types, of 200 trees each replicated five times at a spacing of 1.5m. Survival and total and current annual height were assessed after the first, second, fifth and eighth growing seasons.

White pine was planted on the following four sites: (1) in sod near Midhurst, (2) in a cultivated field near Midhurst, (3) in sod in Medonte township (44°40'N, 70°40'W), and (4) in sod in Rideau township (45°05'N,

75°50'W). All trees were planted by spade except in Medonte township where the trees were planted by both spade and machine. The Midhurst sod and cultivated sites had soil of clay loam while the Medonte township site had a sandy loam soil. The soil of the Rideau township plant was a shallow, coarse loamy sand over limestone bedrock. At Midhurst, four stock types were planted in a randomized complete block design with 200 trees per plot,replicated five times.In Rideau township a fifth stock type (3+0 from Kemptville nursery) was added. In Medonte township only 100 trees were planted per plot. All trees were planted at a spacing of 1.5 m. Total height, current annual increment and survival were assessed each autumn for five years.

Red pine was planted at Midhurst, and at Napanee and Carleton Place in eastern Ontario. The Midhurst site was an abandoned nursery compartment with a soil of nutrient deficient, deep fine sand. There was little or no competition, even after three years (Racey and Hutchison 1984). The sites in eastern Ontario were abandoned farmland with soils of deep fine sands. Grass competition was intense. At the Midhurst site three red pine stock types from Midhurst nursery were planted. At Napanee and Carleton Place, seven stock types from Orono(43°59'N,78°37'W), Kemptville (45°02'N, 75°39'W) and Midhurst nurseries (Table 1) were planted with 49 trees per plot replicated five times. Spacing was approximately 2m between trees. After hand planting, the vegetation around the trees was spot sprayed for weed control with .37 kg/ha ai simazine and .37 kg/ha ai amitrol-T. Total height, current annual increment and survival were assessed each autumn for 4 years.

Survival, total height and CAI data were analysed by analysis of variance. To compare stock performance the following three measures of relative growth were calculated for each age class.

1. Relative growth rate = (Present height/original planting height)/ years since outplanting) $(cm.cm^{-1}.yr^{-1})$
2. Annual net growth = (Present height/No. of years from seed) $(cm.yr^{-1})$
3. Aggregate height = Average height x percent survival (cm)

**Results**

In Ontario, planting stock is frequently classified by age class and size with the two often used synonymously. Shoot length, root collar diameter and oven dry weight are the most frequently used parameters for grading (Reese and Sadreika 1979). The various stock types used in the experiments described here varied greatly in morphological characteristics (Table 1). Seedling stock tended to have lower dry weight, but greater height to diameter ratio or sturdiness quotient (Roller 1977) than transplant stock of a similar chronological age. The Midhurst stock was large by Ontario shipping stock standards (Reese and Sadreika 1979) while the Orono and Kemptville stock was medium to small.

White spruce

The advantage of large size white spruce planting stock in survival was still evident eight years after outplanting (Table 2). On the cultivated sites the 1.5+1.5 stock had significantly better survival and height growth than either the 3+0 or 2+0 planting stock, but on the heavy competition site only survival was significantly different (Table 2). The difference in size between the transplant and seedling stock was still evident but the variation among individual trees was so great that these differences were not statistically significant. However, the reduction in growth was more pronounced for the 2+0 and 3+0 stock than the 1.5+1.5 stock (Table 3).

Table 2 Average height, annual height increment and percent survival eight years after outplanting for 3 stock types of white spruce planted on a cultivated and on a sod site.

| Age class | Height (cm) | Current annual increment (cm) | Survival % | Annual net growth | Relative growth rate $cm.cm^{-1}.yr^{-1}$ | Aggregate height m/100 trees planted |
|---|---|---|---|---|---|---|
| Cultivated plant | | | | | | |
| 2+0 | 157.4 c | 23.6 b | 62.4 b | 17.4 | 1.08 | 98 |
| 3+0 | 184.2 b | 24.9 b | 73.3 b | 19.4 | .79 | 135 |
| 1.5+1.5 | 249.2 a | 35.0 a | 98.6 a | 26.6 | .86 | 246 |
| | *** | *** | ** | | | |
| Sod plant | | | | | | |
| 2+0 | 132 | 25 | 20.6 b | 14.2 | .91 | 27 |
| 3+0 | 136 | 27 | 19.4 b | 13.4 | .59 | 26 |
| 1.5+1.5 | 166 | 29 | 61.7 a | 16.2 | .58 | 102 |
| | ns | ns | ** | | | |

** significant at 99% level of significance
ns not statistically significant
Numbers followed by similar letters are not significantly different at the 95% level.

Table 3 Average eighth year aggregate height (m/100 trees planted) for 3 white spruce stock types planted on low and heavy competition sites at Midhurst.

| Stock type | Competition level | | |
|---|---|---|---|
| | Low | High | Percent reduction in growth |
| 2+0 | 98 | 27 | 72 |
| 3+0 | 135 | 26 | 80 |
| 1.5 + 1.5 | 245 | 102 | 58 |

White pine

The 1+2 white pine transplants outperformed all other stock types on nearly all five sites while the 3+0 and 2+1 grew least (Table 4). The superior growth of the 1+2 stock is primarily attributable to the rapid growth during the first two years after outplanting as shown by the Midhurst outplanting (Figure 1). There was a difference in overall performance as represented by aggregate height over the range of planting sites (Table 5). The lowest aggregate height values were measured on the Midhurst cultivated site and the Rideau shallow-soil, heavy competition sites. In both of these plantations, the 1+2 transplant stock had a significantly better performance than the seedling stock (Table 4). Also, the 3+0 and 2+1 stock types had their total production, as measured by aggregate height, reduced substantially more on the heavy competition Rideau site than the other age classes, as compared with aggregate height on the most productive Medonte site (Table 5). The difference between hand and machine planting appears to be minimal.

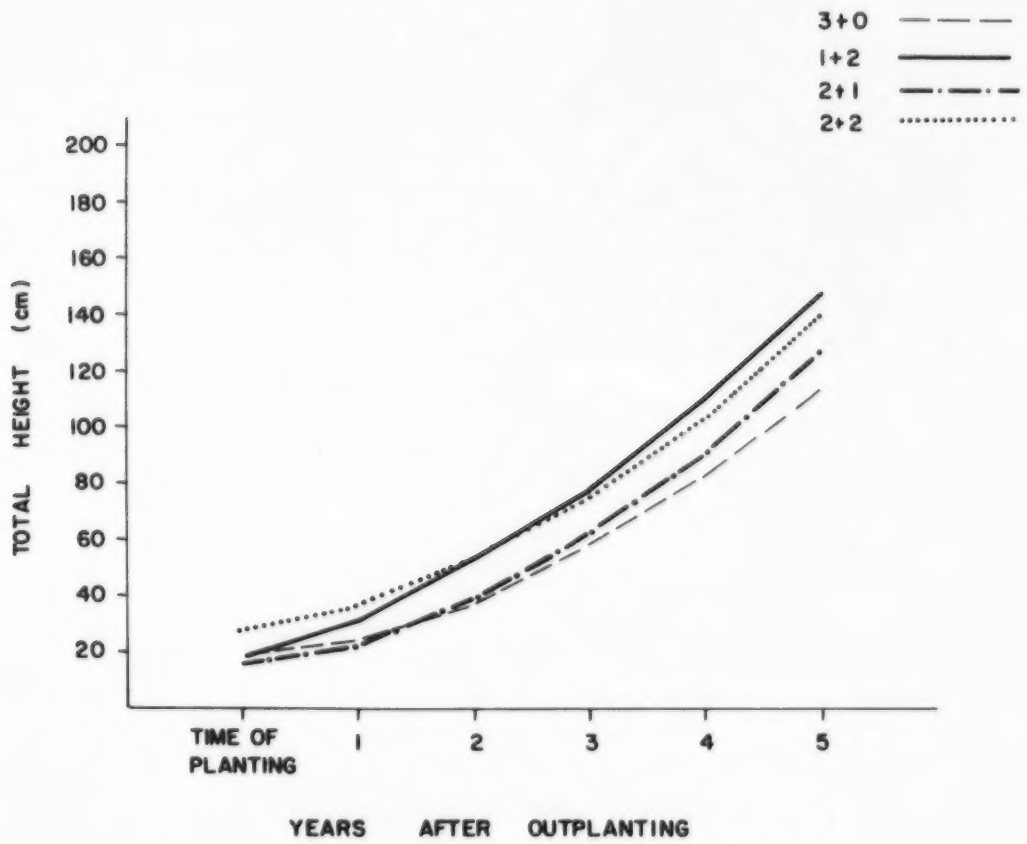


Figure 1 Average total height of four white pine stock types grown for 5 years on a cultivated clay loam soil at Midhurst, Ontario.

Table 4 Average height, current annual increment and percent survival five years after outplanting of four white pine stock types planted on several sites by hand or machine.

| Stock type | Height | Current annual increment | Percent survival | Relative growth rate $cm.cm^{-1}.yr^{-1}$ | Annual net growth cm | Aggregate height m/100 trees planted |
|---|---|---|---|---|---|---|
| Medonte hand plant | | | | | | |
| 3+0 | 161 b | 45 b | 94 b | 1.40 | 27.5 | 151 |
| 1+2 | 194 a | 52 a | 100 a | 1.94 | 34.8 | 194 |
| 2+1 | 150 c | 43 b | 95 b | 1.58 | 26.2 | 143 |
| 2+2 | 161 b | 45 b | 96 b | 1.24 | 27.1 | 155 |
| | *** | *** | *** | | | |
| Medonte machine plant | | | | | | |
| 3+0 | 153 c | 40 b | 97 | 1.33 | 25.9 | 148 |
| 1+2 | 185 a | 47 a | 100 | 1.85 | 33.0 | 185 |
| 2+1 | 151 c | 42 b | 96 | 1.59 | 26.4 | 145 |
| 2+2 | 162 b | 44 ab | 98 | 1.25 | 27.2 | 159 |
| | *** | *** | ns | | | |
| Midhurst sod plant | | | | | | |
| 3+0 | 127 | 31 | 88 b | 1.10 | 20.7 | 112 |
| 1+2 | 157 | 31 | 97 a | 1.57 | 27.4 | 152 |
| 2+1 | 127 | 27 | 94 a | 1.34 | 21.6 | 119 |
| 2+2 | 153 | 34 | 96 a | 1.18 | 25.4 | 147 |
| | ns | ns | * | | | |
| Midhurst cultivated plant | | | | | | |
| 3+0 | 114 c | 29 b | 68 c | .99 | 18.1 | 78 |
| 1+2 | 147 a | 37 a | 98 a | 1.47 | 25.4 | 144 |
| 2+1 | 127 b | 34 ab | 95 b | 1.34 | 21.6 | 121 |
| 2+2 | 139 ab | 33 ab | 96 ab | 1.49 | 22.6 | 133 |
| | *** | * | *** | | | |
| Rideau sod plant | | | | | | |
| 3+0 | 65 b | 13 | 45 b | .57 | 8.3 | 29 |
| 1+2 | 87 a | 18 | 79 a | .87 | 13.4 | 69 |
| 2+1 | 66 b | 14 | 68 a | .70 | 9.4 | 45 |
| 2+2 | 87 a | 19 | 74 a | .67 | 12.2 | 64 |
| [1]KV 3+0 | 70 b | 15 | 22 c | .54 | 8.9 | 15 |
| | ** | ns | ** | | | |

* significant at 95% level
** significant at 99% level
*** significant at 99.9% level

Numbers followed by similar letters are not significantly different at the 95% level.

1 White pine 3+0 stock from G. Howard Ferguson Forest Station, Kemptville.

Table 5 Aggregate height (m/100 trees planted) for 4 white pine stock types planted on 5 sites, ranging from low to very heavy vegetative competition (left to right). The Rideau plant was on a fresh, shallow soil over limestone bedrock. The percent reduction in growth was calculated by comparing the growth on the best site with the growth on the worst sites.

| Stock type | Midhurst | Medonte | | Midhurst | Rideau | Percent reduction in growth |
|---|---|---|---|---|---|---|
| | Cultivated plant | Machine plant | Hand plant | Sod plant | Sod plant | |
| 3+0 | 78 | 148 | 151 | 112 | 29 | 80 |
| 1+2 | 144 | 185 | 194 | 152 | 69 | 62 |
| 2+1 | 121 | 145 | 143 | 119 | 45 | 68 |
| 2+2 | 133 | 159 | 149 | 147 | 64 | 60 |

Red pine

The large stock types survived significantly better than the small stock types (Table 6) and these differences were more pronounced on sites with heavier vegetative competition. At the Midhurst site with no competition all stock survived equally well. However, general survival declined on the medium to heavy sod at Napanee and Carleton Place. The 1+1 and 2+0 stock types suffered heavy mortality on the Carleton Place site which had extremely heavy grass competition. Mortality of the small stock types on the Carleton Place site may have been due to the joint effects of herbicide applications and heavy vegetative competition. Some yellowing of needles was observed, which could be due to Simazine and Amitrol-T. Survival of the large planting stock was reduced but to a lesser degree than the small stock types in the heavy competition sites.

The 1+2 stock was significantly taller than all other stock in the Midhurst and Carleton Place plantations, but was not significantly different from the other three-year-old stock in the Napanee plantation. The height of the 2+0 red pine was not significantly different from the 3+0 stock in the Midhurst plantation or the Kemptville and Orono 3+0 stock in the Napanee plantation, but was significantly smaller at the Carleton Place site. Overall productivity in terms of aggregate height (Table 7) was reduced 73 percent for the 2+0 stock, 20 percent for the 3+0 and not at all for the 1+2 stock.

**Discussion**

Nursery stock in Ontario is classified by age classes and size classes. Size of nursery stock is often positively correlated with outplanting performance (Chavasse 1977, Zaerr and Lavender 1976, Yli-Vakkuri et al. 1968, Nienstaedt 1981). However, some measures of size such as diameter, root volume or weight tend to be better indicators of outplanting performance than shoot length or top-root ratio (Glerum 1988, Racey et al. 1983a, Chavasse 1977, Edgren 1977, Zaerr and Lavender 1976).

Table 6 Average height, current annual increment and percent survival four years after outplanting for 7 red pine stock types planted in several Ontario locations.

| Stock type | | Height cm | Current annual increment cm | Survival % | Annual net growth | Relative growth rate $cm.cm^{-1}.yr^{-1}$ | Aggregate height m/100 trees planted |
|---|---|---|---|---|---|---|---|
| Napanee | | | | | | | |
| Orono | 2+1 | 81 abc | 20 | 76 ab | 11.6 | 1.06 | 62 |
| Orono | 3+0 | 87 ab | 21 | 71 ab | 12.4 | .73 | 62 |
| Midhurst | 1+2 | 82 abc | 18 | 79 ab | 11.7 | .83 | 65 |
| Midhurst | 3+0 | 99 a | 27 | 87 a | 14.1 | .92 | 86 |
| Kemptville | 1+1 | 60 c | 16 | 39 c | 10.0 | 1.92 | 23 |
| Kemptville | 2+0 | 71 bc | 23 | 72 ab | 11.8 | 2.43 | 51 |
| Kemptville | 3+0 | 75 abc | 18 | 60 bc | 10.7 | .70 | 45 |
| | | * | ns | * | | | |
| Carleton Place | | | | | | | |
| Orono | 2+1 | 71 b | 14 bc | 83 ab | 10.1 | .92 | 59 |
| Orono | 3+0 | 75 b | 15 b | 82 ab | 10.7 | .64 | 62 |
| Midhurst | 1+2 | 88 a | 20 a | 90 a | 12.6 | .89 | 79 |
| Midhurst | 3+0 | 69 b | 14 bc | 63 b | 9.8 | .59 | 43 |
| Kemptville | 1+1 | 49 c | 12 b | 28 c | 8.2 | 1.57 | 14 |
| Kemptville | 2+0 | 48 c | 11 c | 33 c | 8.0 | 1.60 | 16 |
| Kemptville | 3+0 | 69 b | 15 b | 67 b | 9.8 | .64 | 46 |
| | | *** | *** | *** | | | |
| Midhurst | | | | | | | |
| Midhurst | 2+0 | 59 b | 13 b | 99.9 | 9.8 | 1.46 | 59 |
| Midhurst | 3+0 | 63 b | 12 c | 99.9 | 9.0 | .58 | 63 |
| Midhurst | 1+2 | 74 a | 15 a | 100.0 | 10.5 | .83 | 74 |
| | | *** | ** | ns | | | |

* significant at 95% level
** significnt at 99% level
*** significnat at 99.9% level
Numbers followed by similar letters are not significantly different at the 95% level.

Nursery cultural treatments associated with each age class contribute significantly to the morphology of nursery stock. Transplant stock is generally more robust than seedling stock (Racey and Hutchison 1984, Wood 1984, Racey et al. 1983b, Edgren 1977) and this is generally cited as a major factor in the improved performance of transplant stock over seedling stock (Glerum and Paterson 1985, Racey and Hutchison 1984, Wood 1984, Mullin and Christl 1982, Mullin and Howard 1973).

In the red pine trials the 1+2 transplants were shorter than the seedling stock at time of planting but had significantly larger stem diameters and weights. The 1+2 red pine stock was affected least by

Table 7 Average fourth year aggregate height (average height (m) x percent survival) for 5 red pine stock types on 3 sites which had low, medium to high and high vegetative competition.

| Stock type | Competition level | | | Percent reduction in growth[1] |
|---|---|---|---|---|
| | Low | Medium-high | High | |
| 2+0 | 59 | 51 | 16 | 73 |
| 3+0 | 63 | 64 | 50 | 20 |
| 1+2 | 74 | 65 | 79 | -7 |
| 2+1 | ND | 62 | 59 | 4 |
| 1+1 | ND | 23 | 14 | 41 |

ND No data available
1 Percent reduction in growth was determined only for the differences between medium-high and high vegetative competition

increasing levels of vegetative competition (Table 7) and generally had the best growth in all plantations. The one exception was the Midhurst 3+0 stock which grew better than the 1+2 transplants in the Napanee plantation (Table 6).

The small 2+0 red pine performed well on the low competition sites, but performed poorly under heavy competition. Therefore intensive competition control will be necessary for this stock to succeed on heavy competition sites. The 2+1 red pine stock was comparable in performance with the 3+0 stock, but has done poorly in other plantations (Glerum and Paterson 1985) and is therefore no longer produced in Ontario.

In the white spruce plantations, where the transplant stock was not only more robust, but also taller at time of planting, the aggregate height of the transplant stock on the low competition site was at least 81% higher than that of the seedling stock. On the heavy competition site it was 290% higher (Table 2). In addition, the percent reduction in overall performance due to increased competition was 58% for the 1.5+1.5 stock as compared with 72 and 80% for the 2+0 and 3+0 stock respectively. The importance of stock type and size therefore appears to become more important with increasing vegetative competition.

The 1+2 white pine stock was generally superior on all sites and compared favorably with the large 2+2 planting stock (Table 4). Overall, total aggregate height was best on the deeper sands with moderate levels of competition. Aggregate height was reduced on the poor Rideau site (shallow soils, fresh, heavy competition) but the reduction in performance was similar between the 1+2 stock and 2+2 stock (Table 5) and both of these stock types were affected less by competition than the 3+0 and 2+1 stock.

The major advantage in growth of the 1+2 pine planting stock appears to be the large leader elongation in the first year after outplanting (Glerum and Paterson 1985, Racey and Hutchison 1984). This growth characteristic is also evident from the white pine growth curves (Figure 1). The ability of

this stock type to elongate has been created by the sequence of cultural practices in the nursery, particularly the 1+2 transplanting process. The transplanting process creates a wider, more even spacing among trees, reduces second year top growth while encouraging root growth, which results in a more robust seedling (Mullin 1981, Chavasse 1977, Mullin and Bowdery 1977).

Other practices beside transplanting are being adopted at forest tree nurseries to create more suitable planting stock. These practices involve root pruning and wrenching (Tanaka et al. 1976, van Dorsser and Rook 1972, Mullin 1966).

There is little doubt that cultural practices such as modifying seedbed density, transplanting and root wrenching modify the morphology of stock. However, what is more important are the physiological processes, which cause these morphological changes to occur. After all, the morphological condition of the stock is an irreversible record of the physiological history of the tree. Thus, the field performance trials are an essential tool to provide information on the effects of alternative cultural practices.

The trials described in this report show that the current nursery practices produce seedling stock which is inferior to transplant stock particularly on high competition sites. Seedling stock, such as 2+0 red pine and 3+0 white pine are low cost alternatives to transplant stock for planting on low competition sites. However, the aim of the nurseries should be to use seedbed spacing, root pruning and wrenching or fertilization to produce seedling stock, which is as productive as transplant stock.

The results of these trials show that the currently produced transplant stock is superior to seedling stock on all sites. However, a stock type is more than an age class. It is the fitness for purpose which is expressed by the physiological quality of the stock to perform well on the chosen site. The attributes of suitable stock must be identified and the nursery practices tailored to produce stock with those attributes. Desirable attributes can only be identified through comprehensive outplanting trials on a variety of sites and feedback is required to further improve nursery cultural practices.

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